SESIMIC SOURCE CHARACTERIZATION IN ASIA

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Sponsored by U.S. Department of Energy
Office of Nonproliferation Research and Engineering
Office of Defense Nuclear Nonproliferation
Nation Nuclear Security Administration

ABSTRACT

A significant challenge of modeling small-to-moderate-size seismic sources is the necessity of relying on short-period signals with long travel paths that are significantly sensitive to earth structure along the path. When the path effects are unknown or difficult to account for, we must rely on components of seismic signals that are minimally dependent on the structure. Although regional surface-wave phase is strongly influenced by structure, surface wave amplitude spectra can be modeled adequately with relatively simple models, and these spectra carry valuable information on source character and depth. Our efforts build on existing seismic source analysis techniques. We directly model regional seismograms where possible but combine those time-domain observations with surface wave amplitude spectra at more distant regional stations. We have used regional seismic data to estimate seismic moment tensors and event depths for characterization of seismic sources in Asia. For larger events in the study (greater than magnitude 5) we have successfully included long-period (approximately 40 seconds period) body-wave trains that can be modeled reliably using simple stratified earth models into our grid search for strike, dip, rake, moment, and depth. Our main focus is to use regional seismic data to estimate seismic source mechanisms, moments, and event depths to characterize seismic sources in Asia. A complete catalog of regionally estimated seismic moments, source mechanisms, and depths will be a useful tool for magnitude calibration and regional characterization. Recent work has suggested possible bias in Harvard CMT moment estimates for events in central Asia (Patton, 1998). Thus, we are particularly interested in constraining seismic moments, which are critical for calibrating regional magnitude scales with global catalogs, and in improving depth estimates for Asian events. In the broader view, accurate seismic source parameters for small-to-moderate size events is a step towards the construction of path-specific or regional, short-period (less than 15 seconds) surface-wave dispersion maps, which are essential for creating matched filters for isolating and analyzing short-period surface waves from small events.

Key Words: seismic source characterization, magnitude calibration, regional characterization, regional wave propagation

OBJECTIVE

We need a catalog of regionally estimated seismic moments, source mechanisms, and depths for magnitude calibration and regional characterization. Recent work has suggested possible bias in Harvard CMT moment estimates for events in central Asia (Patton, 1998). Further modeling studies (Patton and Randall, 2000) suggest that the bias in CMT moment estimates depends on the source mechanism. If we are to develop a catalog of accurate moment estimates, we must refine techniques for regional moment tensor estimation to use all available data. We are focusing on using joint modeling of time domain regional waveforms, regional surface wave spectra, and teleseismic bodywaves. Time domain regional waveform modeling has been a useful tool in Asia (Randall, Ammon & Owens, 1995) when the earth model is suf-

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **Sesimic Source Characterization In Asia**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Los Alamos National Laboratory,Los Alamos ,NM,87545**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings of the 22nd Annual DoD/DOE Seismic Research Symposium: Planning for Verification of and Compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT) held in New Orleans, Louisiana on September 13-15, 2000, U.S. Government or Federal Rights.

14. ABSTRACT
See Report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

ficiently accurate and the propagation path short enough to accurately characterize the surface wave dispersion. For longer paths, we are jointly modeling the regional surface wave spectra which are less sensitive to the details of the dispersion. The amplitude of the surface wave spectrum is a nonlinear function of the moment tensor estimate, so we have adopted a grid search over strike, dip and rake rather than formulate an iterative nonlinear inversion scheme. Although surface wave spectra are unable to resolve the mechanism polarity, as little as one time domain waveform can resolve the ambiguity.

RESEARCH ACCOMPLISHEMENTS

We are developing a complete catalog of regionally estimated seismic moments, source mechanisms, and depths for Asia and refining techniques for regional moment tensor estimation to develop the catalog. Our present efforts have focused on a number of well recorded regional events which also have CMT (Dziewonski et al., 1983) estimates.

We show some of the work for an event in western China on January 30, 1999, at 41.674N latitude and 88.463E longitude with a 23.3 km. depth. Only station WMQ is close enough to permit regional time domain modeling. The maps in Figure 1 show a polar projection centered on the event, out to 90 degrees distance, and the regional view of the event with paths to stations used to analyze the event. Although there are many more stations at teleseismic distance, for smaller events the signal will only have useful signal to noise at the regional and closer teleseismic stations.

In Figure 2 we show the results of the moment tensor estimation using both the L1 and L2 error norms, and the CMT solution with its best double couple fault planes. The CMT solution shows the moment tensor solution with the shaded region, and the best double couple is shown by the focal planes. The regional solutions are inherently double couple as they are found with a simple grid search over strike, dip and rake. All three solutions have a near horizontal compressional axis and a near vertical tensional axis, although details of the fault planes are apparent.

Figure 3 shows the full waveform regional time domain fits at WMQ, regional surface wave spectral fits at ULN for both vertical Rayleigh and tangential Love waves, and time domain waveforms for vertical component long period body waves including both the P wave and the S wave. For the time domain fits, the bold waveforms are the synthetic and the fine lines are the data. For the spectral fits, the solid curve and the circles are the data and the triangles are the predictions, with errors computed at the discrete frequencies of the circles and triangles. Broadband data and Green’s functions are used in the modeling, and both data and Green’s functions are filtered in the modeling code to permit simple changes of filter parameters with a single set of waveforms. The WMQ and ULN data have been bandpass filtered from 100 to 20 seconds period; more distant body wave data at HIA and YAK have been bandpass filtered from 50 to 40 seconds period. The results shown are for 25 km. depth which had the minimum error for the range to depths modeled. All Green’s function were calculated with a reflectivity algorithm and an earth structure using regional earth models overlying a mantle from the PREM model. This should give results that accurately reflect both regional and teleseismic propagation.

Figure 4 shows a preliminary attempt to model broadband teleseismic P waves for source

depth. The data for the broadband vertical component for station EIL (bold trace) are compared to Green's functions (narrow traces) for depths shown at the right margin of the trace. The Green's function is not meant to accurately represent the moment tensor, but only to show the potential for resolving event depth in addition to the analysis of regional data. In this case, the EIL data suggest a depth between 20 and 25 km. which is comparable to the results of our modeling and the published 23.3 km. depth.

CONCLUSIONS AND RECOMMENDATIONS

We have developed techniques to estimate seismic moment tensors by jointly modeling near regional broadband seismograms, regional surface wave spectra and body waves at far regional and teleseismic distances. We will apply the technique to all events in Asia to build a complete catalog of seismic moment tensor estimates and determine the minimum moment we can expect to accurately model in the region. Well recorded events will also be analyzed for surface wave dispersion and phase matched filters developed for event station paths. Analysis of fundamental mode surface wave spectra using mode isolation based on the dispersion will also be investigated. The dispersion measurement will be included in regional tomographic studies for regionalization of surface wave propagation.

This document is LAUR-00-2583

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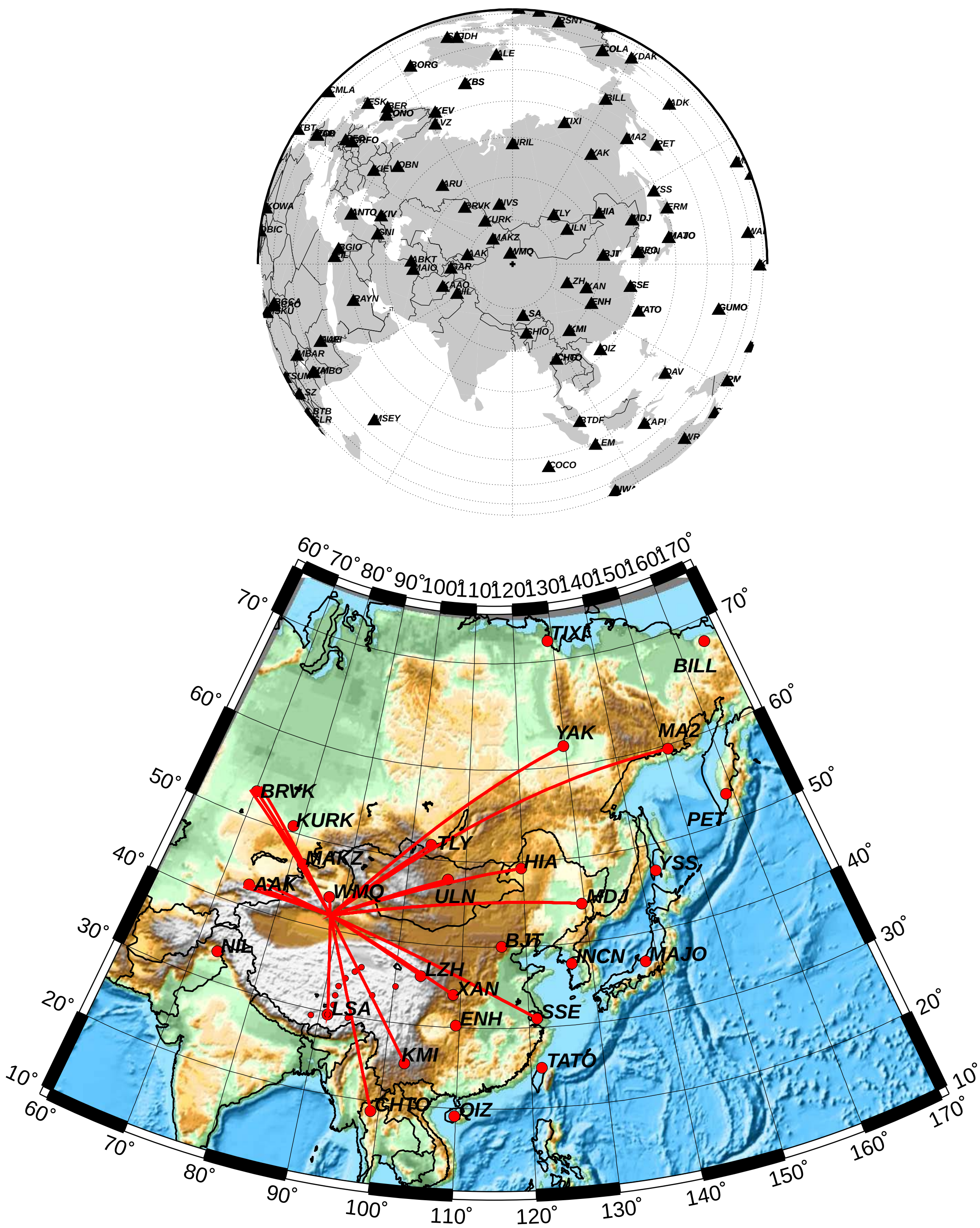

Figure 1. Maps showing teleseismic and regional station distributions with regional paths.

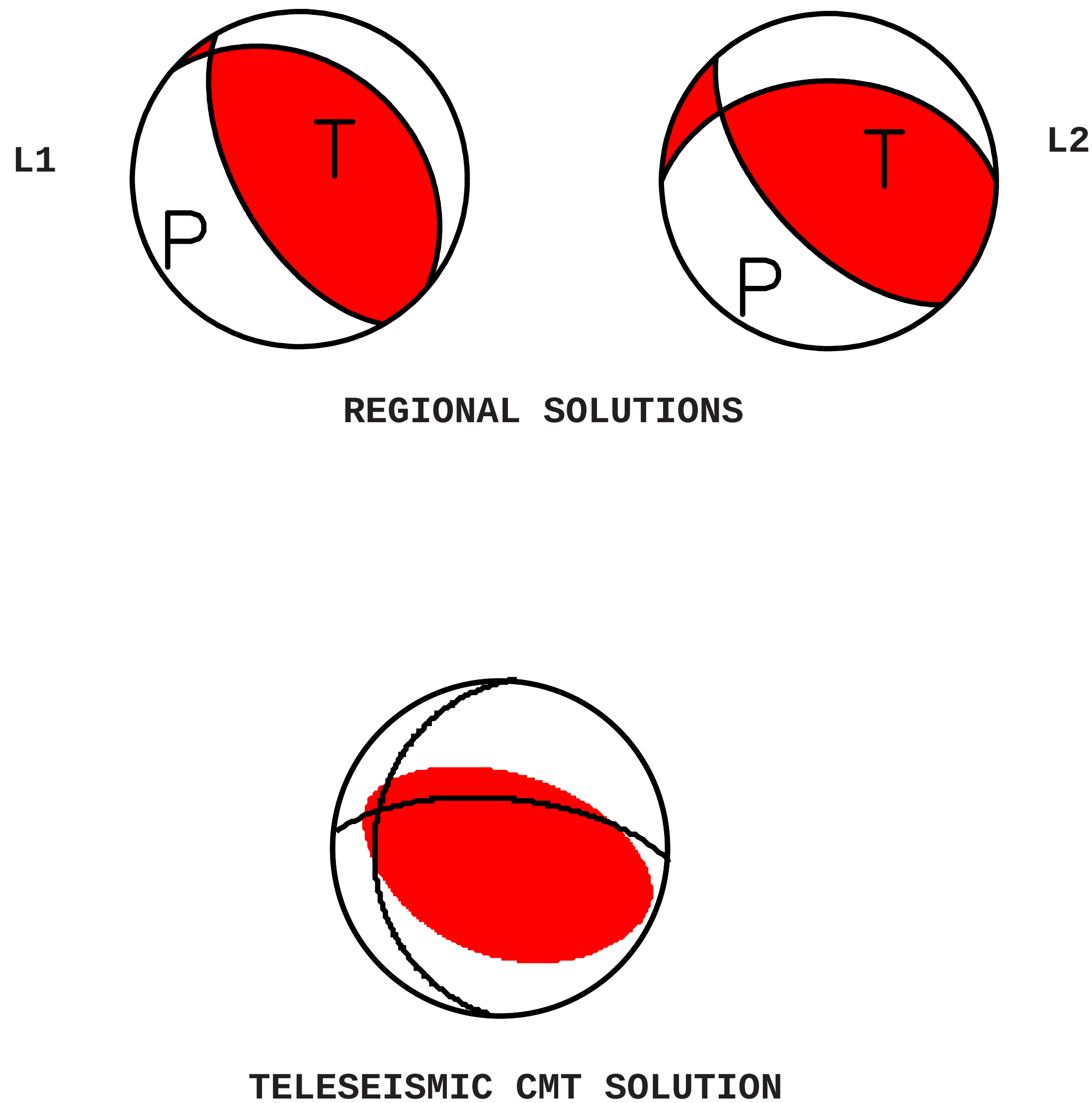

Figure 2. Comparison of regional solutions using L1 and L2 norms for the grid search and the CMT mechanism.

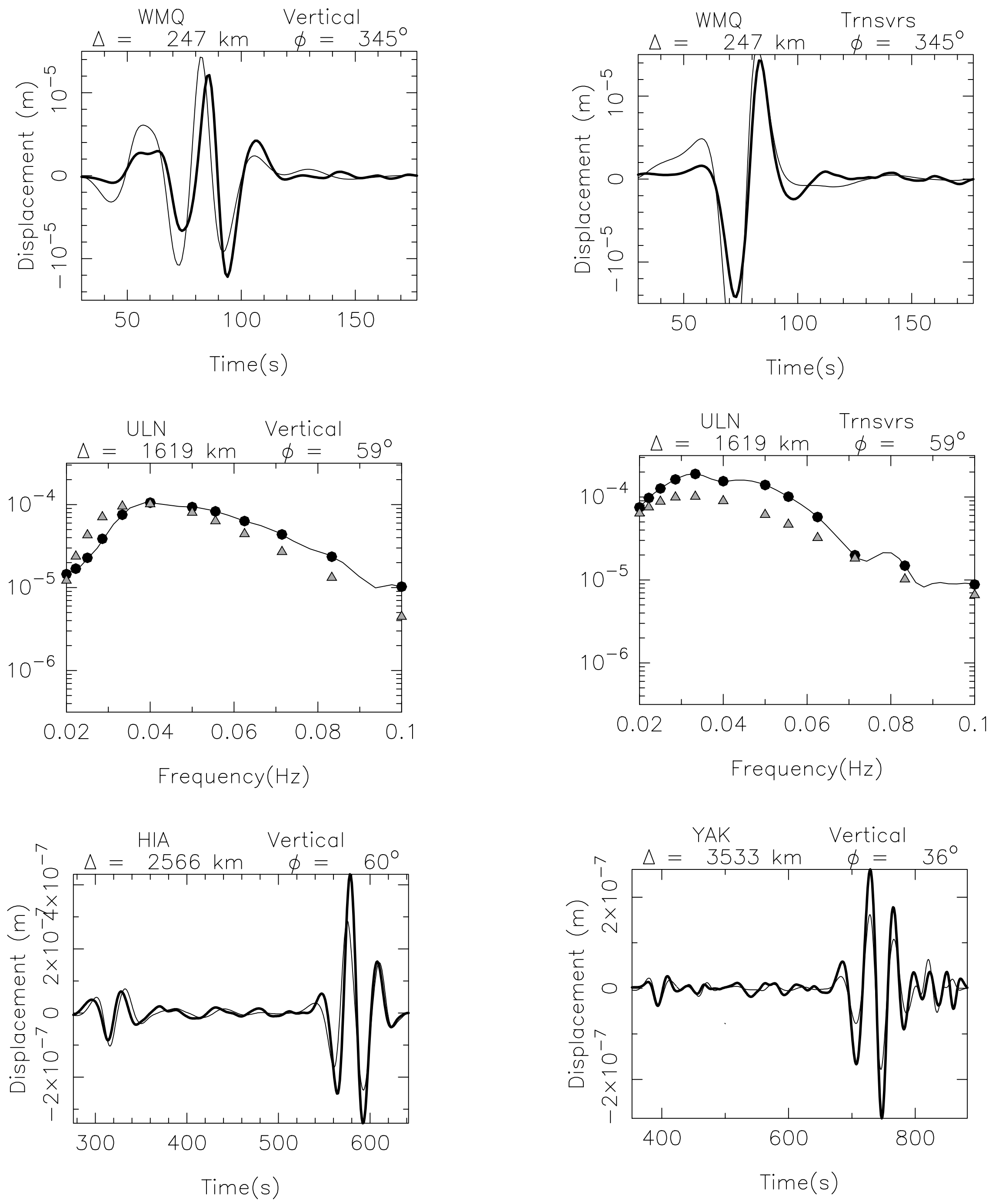

Figure 3. Examples of fits for regional time domain seismograms, regional surface wave spectra, and far regional and teleseismic bodywaves.

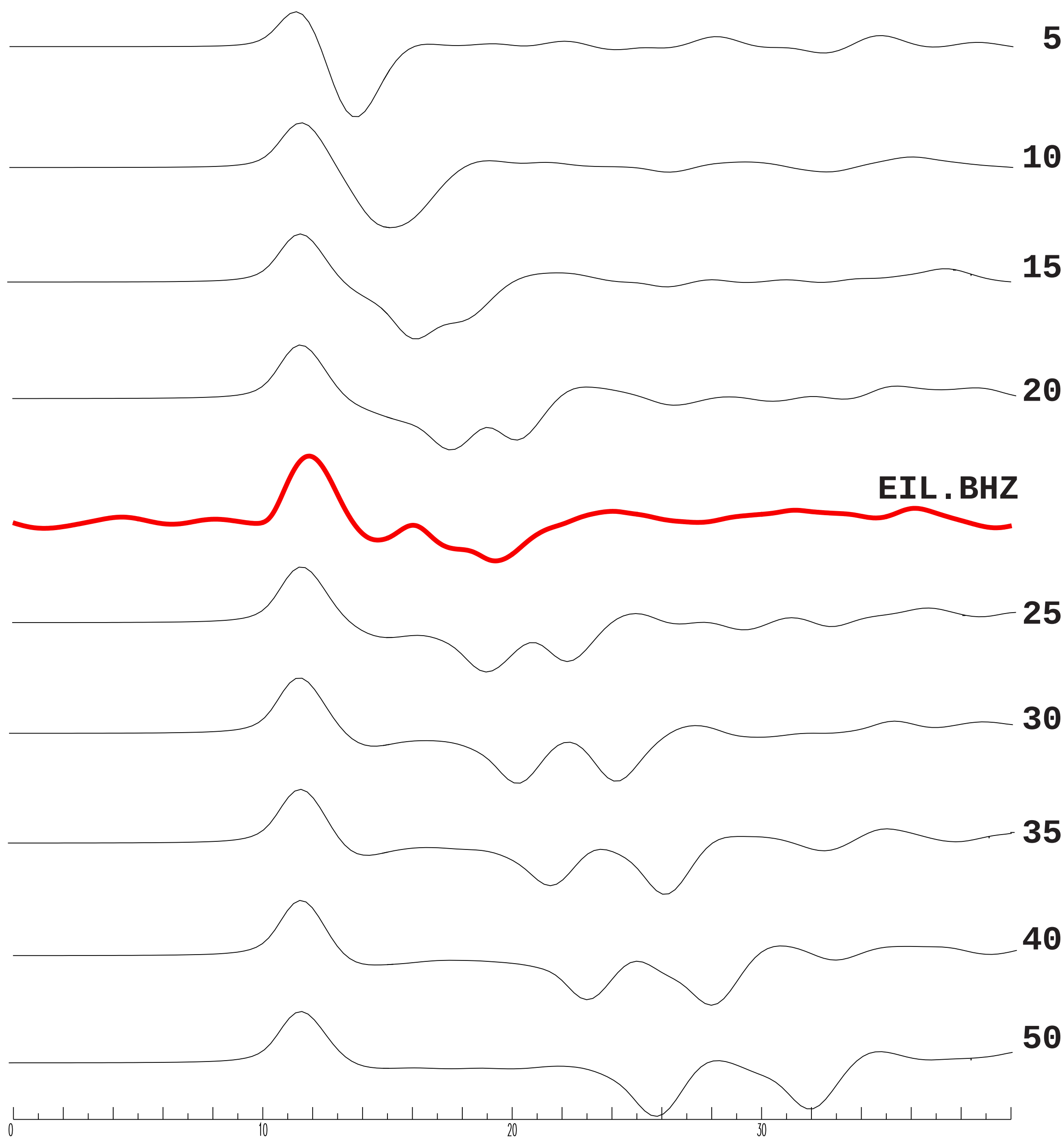

Figure 4. Comparison of observed vertical displacement at EIL and Green's functions calculated for a range of depths.